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THE EAST COAST OF INDIA

By SUMNER W. CUSHING
State Normal School, Salem, Mass.

Map facing p. 92.

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Introduction. The East Coast of India has been known to geographers for a long time as a low lying stretch of land bordered on the west by mountains which stretch from near Cape Comorin on the south to the Ganges plain on the northeast, and on the east by a shallow water seaboard that makes shipping difficult and at times dangerous if not impossible. This low lying land is known geographically as the Carnatic. More detailed accounts of certain parts are given in government publications. In those of the Geological Survey of India are a number of articles that deal with east coast structures written in the earlier history of the Survey by Mr. R. Bruce Foote and Mr. William King.* These deal with the older formations admirably, in a geologic way, but give only hints concerning physiographic forms and processes. In the District Gazeteers, government publications dealing with numerous aspects of the country and people in the separate districts,† one might expect to find the geography

* Records of the Geol. Survey of India, 1870, Vol. III, p. 11, Foote; 1886, Vol. XIX, p. 143, King; Memoirs of the Geol. Survey of India, 1873, Vol. X, Part 1, Foote; 1880, Vol. XVI, Part 1, Foote; Part 2, King; Part 3, King.

† The "district" in India is analogous to our "state."

of the East Coast definitely treated. In these reports, however, the geology is transcribed from the articles already referred to, the physiographic aspects are treated empirically, if at all, and the geographic phases are in general presented as isolated items.

It was because of this condition in the geographic literature of the East Coast of India, and because the hints it afforded seemed to promise abundant reward to the investigator, that the writer was sent to this section for the academic year of 1910-11 by Harvard University, as a Sheldon Traveling-Fellow for research in geography. The work was proposed by Professor W. M. Davis, and generous leave of absence was granted by Principal J. Asbury Pitman of the State Normal School at Salem, Massachusetts.

The East Coast of India is over 1,200 miles long, a distance as great as from eastern Maine to northern Florida, and the low lying tract itself has an average width of about forty miles. Obviously it was impossible to examine the whole of the area with any degree of care in the time allotted. The first part of the work, therefore, resolved itself into selecting certain sections of the plain that were typical of long reaches and different from one another. This necessitated a hasty reconnaissance of the whole area, followed by intensive study of the chosen sections.

Conditions of Work. The work was greatly facilitated by the helpful attitude of the officials of the Indian Government. Following the suggestion of the Indian Geological Survey, the Government of Madras issued a general order to the heads of the various districts and their subordinates, to give all possible assistance to the undertaking. American and European missionaries who are well distributed along the East Coast in relation to the larger centers, did much to forward the work and make it pleasurable, by giving advice concerning local conditions and offering hospitality of the renowned oriental sort. Then, too, the natives themselves assisted materially by their willingness to talk of their life—the use they make of their environment, and with rare exceptions, by their eager friendliness. The primitive condition of most of the people made the investigation of the life side of the problem easy, except where the influence of the environment is counteracted by that highly complicated and artificial set of rules of conduct, the caste system.

Another point of advantage in the work lay in the fact that the greater part of the whole area investigated is free from obstructing vegetation, so that one can observe from long distances land forms that would otherwise be inconspicuous. The work had been planned

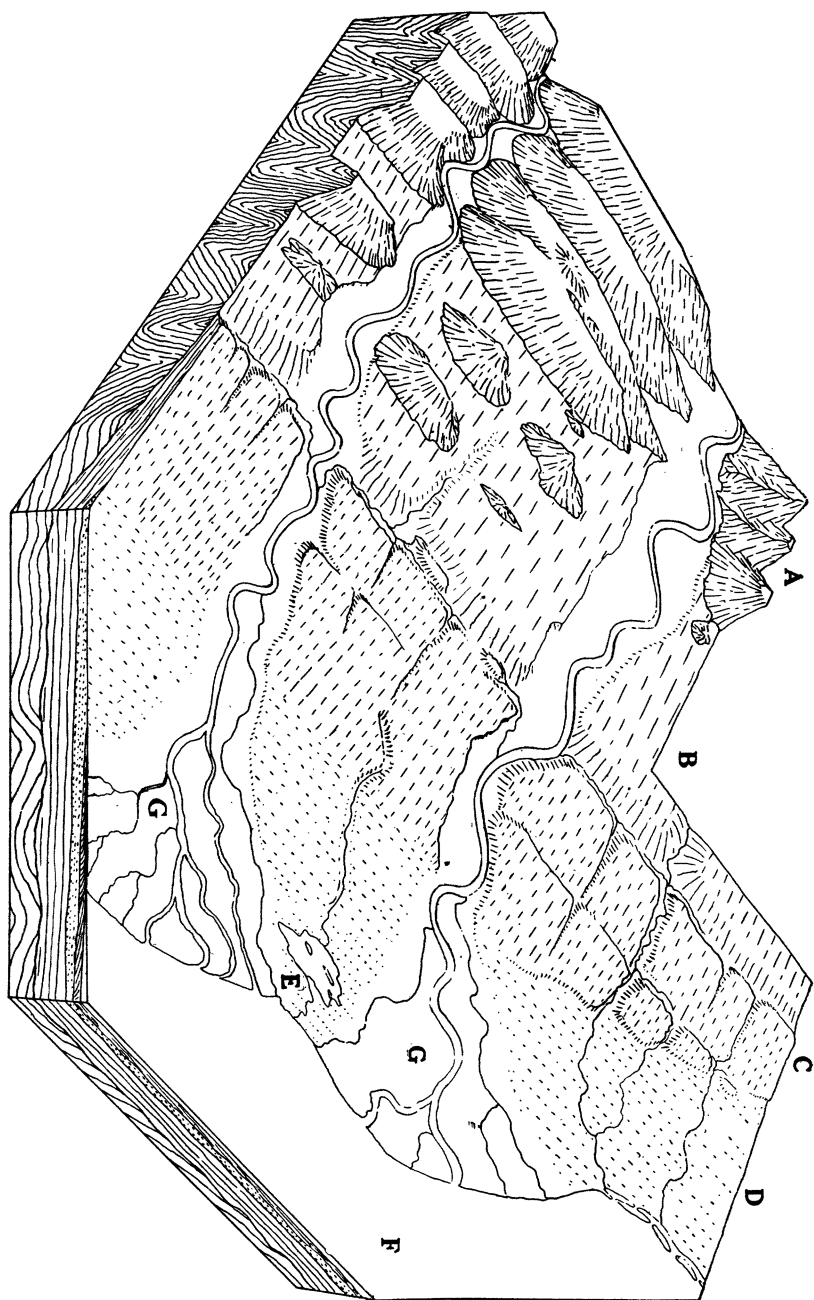


Diagram 1.—Block diagram of a generalized section of the east coast of India. A, elevated peninsular, the Eastern Ghats. B, plain of marine denudation with outliers. C, mature coastal plain. D, young coastal plain. E, strand plain. F, Bay of Bengal. G, type deltas.

for the dry season and the advantage this gave was greater than had been anticipated. The fact that every day was a full working day, except as temperature forbade, and a day when photographic exposures might be made at any hour, can be fully appreciated by those who have experienced the inconveniences of field work in the variable westerlies. The greatest single assisting agent was the railroad that runs the full length of the East Coast and has a number of lateral feeders. Without it the work of days would have been distributed over weeks.

On the other hand, progress was retarded by that all-pervasive oriental lassitude that makes itself evident in meal service, in the work of coolie porters, in the deliberation of petty native officials—in fact whenever the needs of a traveler in India are dependent upon native life—a quality which arouses in the occidental mind a high degree of impatience until it is understood as an environmental product. Primitive means of transportation away from the railroads was another hindering element. The only way of getting about, in many places away from the few large centers, was by two-wheeled carts drawn by bullocks that averaged two and one-half miles per hour. In other sections it was necessary to use elephants because of lack of roads or their need of repair. The surf is so high generally along the coast, owing to the gently sloping sea floor, and roads are so few that much of the coast region could be reached only by houseboats under sail along back water canals, blown by trade winds by day and drawn by coolies at night when the trades weakened. The uncleanness of the people, their inability to supply food suitable for one accustomed to a civilized diet, and the danger of fever bacteria in unboiled drinking water, necessitated carrying a complete camp equipment. As the hot season approached it was found impossible to carry on field work during the mid-day.

Nomenclature. The term “Eastern Ghats” usually designates the “mountains” parallel to the east coast as far south as the Palghat Gap, west of Trichinopoly. (Map, Fig. 1*.) This paper follows a rarer use; here the term is applied as well to the eastern part of the high lands that continue beyond the Gap to Cape Comorin. This part would seem to deserve to be included under that title, for it is the same as the other in form and structure.

The term “Carnatic” has evolved through numerous stages, until now it is applied by the English to mean the low lying land in Southern India on the East Coast, that extends from the foot of the

* Map facing p. 92.

Ghats to the sea. The northern limit varies in use. Geography would do well to appropriate the term for designating the plains bordering the Bay of Bengal southwest of Calcutta. This would require only a slight expansion of the local application; and it would then stand for a physiographic unit, as will be shown later.

"Coromandel" was used anciently to designate a political division; literally, the land of the Cholas. In early British correspondence it applied to the coast in the vicinity of Madras. Later it stood for the eastern coast of the Madras presidency. In a recent publication for mariners on the ports of India, Coromandel designates, by inference, the whole of the east seaboard, as Malabar does the west. Geography can approve of the last use for it is definite, stands for a coast of uniform character, with minor exceptions that are noted below, and is better than "east seaboard," for that term might be interpreted as the Burmese coast, now that political India includes Burma.

Thus it may be said that this paper treats of the Eastern Ghats, the Carnatic, and the Coromandel.

Physiographic Summary. There extends along the East Coast of India from Cape Comorin to near Calcutta, and from some sixty miles inland to the Bay of Bengal, a strip of country that is made up successively, from west to east, of an elevated peneplain of highly distorted rocks that is nearing maturity, an ancient sea cliff, a plain of marine denudation from which rise many outliers, a mature coastal plain the soil of which is "lateritic," and a young coastal plain whose continuity is interrupted by numerous large deltas and whose coast is fringed with narrow strand plains, sand bars and islands. (Fig 1.)

The Elevated Peneplain. Wherever the Eastern Ghats are climbed the comparative evenness of the summits as contrasted with the valley slopes and the attainment of the same general altitude by the ridges and hills are striking features. (Figs. 2 and 5.) They are even more so when it is ascertained that the structures have no relation to these conditions. In the absence of evidence that marine agents developed such a gently rolling initial surface, such as patches of locally derived marine sediments, resort must be made to sub-aerial forces as causal agents, and the conclusion is reached that this land form, the Eastern Ghats, is an elevated peneplain.

The peneplain has been developed over metamorphic structures mainly. They are represented by numerous schists, gneisses, and quartzites. Wherever the resistant gneisses and quartzites prevail

over large areas or the less resistant members extend in sections where the rivers are wide spaced, the peneplain is still in a youthful stage of dissection, in spite of its ancient elevation. It has been carried past maturity toward old age wherever master streams have established low base levels among the weaker members, as shown in Figs. 3 and 4. Between these two extremes there are all varieties of stages. The master rivers have intrenched meandering courses in the elevated peneplain and a well developed series of subsequent tributaries have evolved a corresponding series of structural ridges. The destructive forces that hewed out the plain to the east that accompanied the invasion of the sea, were evidently halted by highly resistant members, for in many cases the seaward ridge of the Ghats preserves the greatest altitude. The strike of the metamorphic structures is sub-parallel to the coast; thus it follows, that in the maturely dissected Ghats the ridges are sub-parallel to one another and the coast and the master streams are transverse. The average height attained by the peneplain is over two thousand feet; while the maximum, which it reaches in the southwest of Madura, is over six thousand feet. From the peneplain numerous monadnocks rise, some attaining altitudes of eight thousand feet. These are usually of the most resistant portions of the strong members of the metamorphic series. They hint at the depth of rock removed by the denuding agents to produce the peneplain.

The ancient sea wall which forms the eastern slope of the Ghats is shown to be such by its relation to the plain of marine denudation, both being carved out of the same structure already referred to in considering the peneplain, and by a lack of those characteristics which indicate a fault scarp. The word "ghat" means in Hindu "landing-stairs from a body of water." This derivative meaning well applies in likening the old sea cliff to a flight of stairs, or the cliff and the peneplain to the rise and tread respectively of a stair-step. It is seen that the full meaning applies to a nicety in describing the conditions when the sea was at work at the base of the cliff.*

The sea wall is boldest in the south near Kodaikanal, a sanitarium and hill station for South India missionaries, where it rises from the inner margin of the Carnatic to an altitude of over 7,200 feet with an average slope of 32°. (Fig. 5.) In many places it approaches the

* This is not intended to suggest, however, that the application of the term indicates the recognition of early geologic conditions, on the part of the Hindus, though they have a pretty legend concerning similar relations to the Western Ghats that coincides with the views of geology. This is given in "Malabar and Its Folks," by T. K. Gopal Panikkar, 1900, Chap. I.

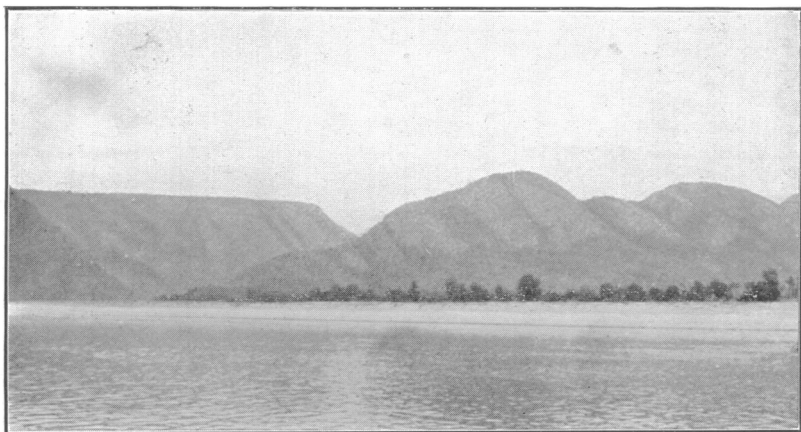


FIG. 2—Northwest of Rajamundry in the elevated peneplain, on the largest river that is entrenched in the Eastern Ghats. The peneplain surface is indicated by the even-crested mountain ridge. Here it has an altitude of 2,700 feet.

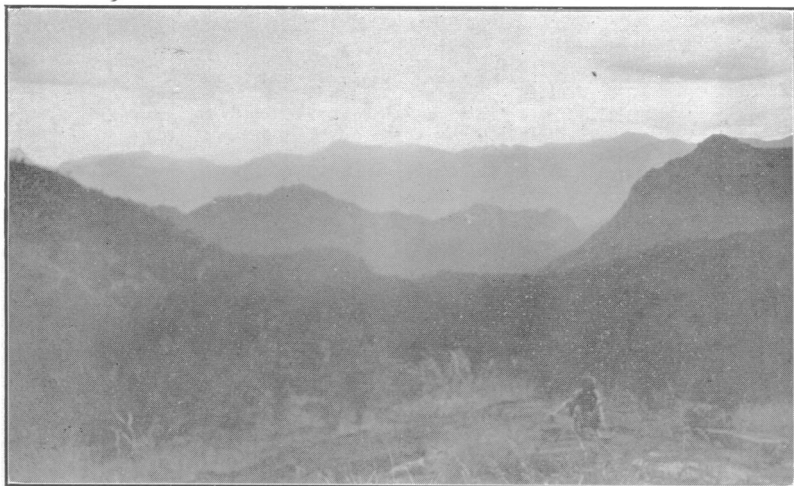


FIG. 3—On the elevated peneplain southwest of Madura. Here erosion has destroyed the peneplain surface except in small patches.

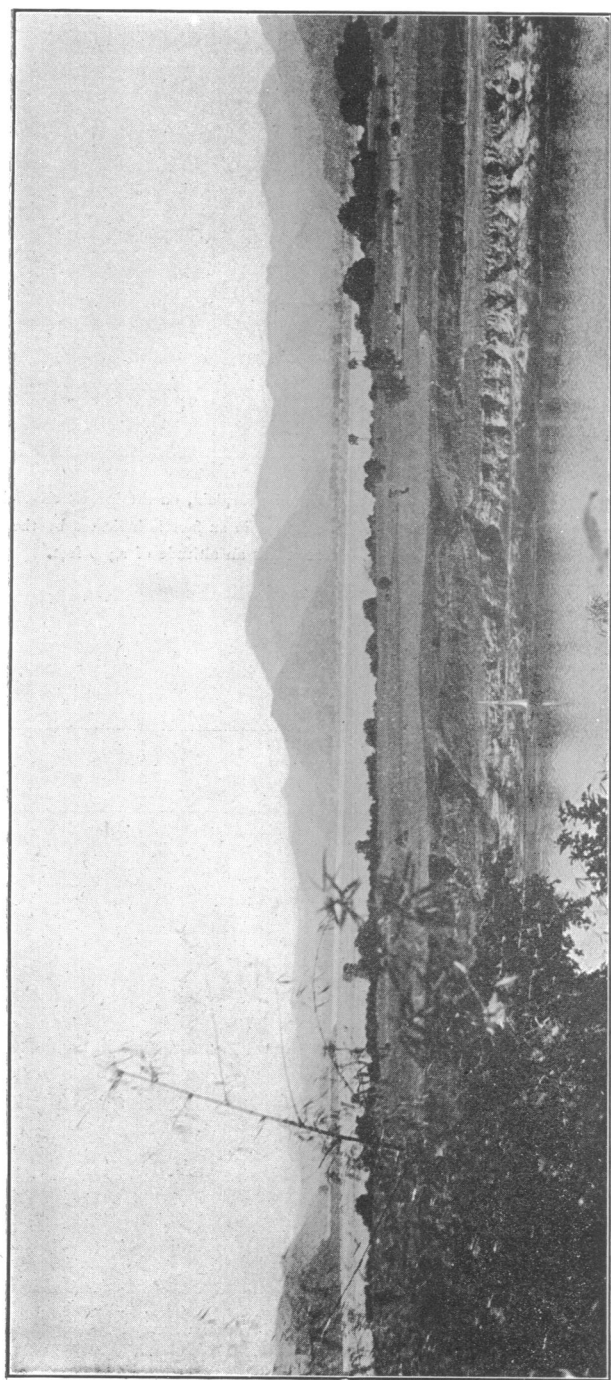


FIG. 4—A less resistant portion of the elevated peneplain bordering the Godavari River, showing advanced dissection and the development of a broad, fertile flood plain.

"sheer precipice" so much recorded in general literature, and so little found in nature. It is so formidable that a bridle path is the only means of ascent. It would seem that the weaker members here underlying the resistant structures permitted the sea to develop a steep sea wall and the drainage of the peneplain to the west helped to preserve it in that condition. In northern sections where the peneplain has a lower altitude the sea wall is less striking in height, and those conditions which gave the peneplain a mature dissection permitted the adjoining sea wall to develop a gentle slope. The sea through its long continued action at the base of the wall searched out the less resistant structures, and with the help of the other denuding agents, made it retreat most where weakest and most exposed; so the sea wall to-day is irregular and fragmentary as is shown in Figs. 6, 7 and Diagram 2.

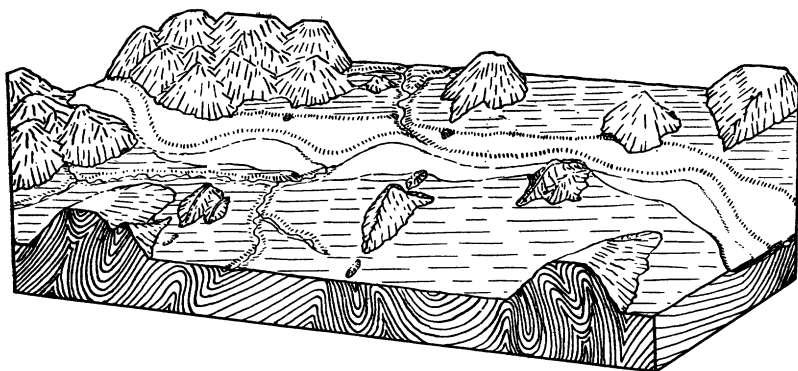


DIAGRAM 2—Block diagram of the plain of marine denudation and its associates, showing some of the finer details.

The Plain of Marine Denudation. The plain of marine denudation, as has been noted above, has been developed in the same metamorphic structures that underlie the peneplain. Because of its low lying altitude and meager rainfall it has been little dissected. In fact the large extended consequent rivers are about the only ones that have disturbed seriously the continuity of the original surface. Even these are in such shallow courses that many have to be "bunded" to prevent the rivers from overflowing the plain during the season of rains. The surface of the plain in extensive sections has become thoroughly "lateritized," *i. e.*, changed to a ferruginous material, in which certain constituents have been replaced by others. This passes by insensible gradations to the unweathered rock which may be less than a foot from the surface. Drainage

ditches along railroads in this belt of country reveal the gradation for hundreds of miles.

There are two striking features of the plain of marine denudation: one is the remarkable evenness of the surface in view of the distorted structures over which it extends; and the other, the prevalence of high steep-sided outliers on the plain. (Diagram 2 and Figs. 8 and 9.) These two features seem to be inconsistent with one another, for if the sea were unable to consume the outliers because of their more resistant material, it would be reasonable to expect an uneven surface to the plain, the minor inequalities of the surface resulting from unconsumed portions of resistant structures. It might be explained, by inferring from this condition and further evidence of structures in the field, that the quartzite of the outliers is separated widely in resistancy from the schists and gneisses of the plain. Wherever metamorphism had developed a fold of quartzite there remained, in the path of the transgressing sea, an outlier to record it. As the sea wall is approached the outliers are more numerous. Those that are near the wall are tied to it by old sand bars and cobble trains, evidently preëlevation beaches. They are rare in the north and south extensions of this plain, and increase rather regularly in numbers toward the center from Bezwada to Vizágapatam and beyond, where they may be said to occupy about eight per cent. of the area. Elevated sea-caves at their bases are not uncommon. (Fig. 11.)

In some sections, particularly those where they are comparatively thick set, the outliers are of about equal heights and have flat summits.* If one is climbed it is seen that the summits lie in the same plane, and further, that this plane, if projected landward, coincides with the elevated peneplain. It dips gently to the south-east or seaward. (Fig. 8.) Here then is an evident memorial to the former extension of the peneplain before the marine erosion, that generated the plain of denudation and the sea wall, and also a convincing demonstration that the limiting wall of the Eastern Ghats is not a fault scarp.

Mature Coastal Plain. Seaward of the denudation plain is a coastal plain of shales and sandstones, containing marine fossils. It dips about 6° to the southeast. This coastal plain has reached maturity in those sections which were lifted most above sea level. This occurred in the central stretches of the East Coast, from Madras to Rajamundry, where the inner margin must have stood

* This relation of the outlier summits was first recorded by William King in the "Memoirs of the Geological Survey of India," Vol. XVI, Pt. 3, p. 10. He interpreted the flat summits as "remnants of a deeply denuded old marine floor."

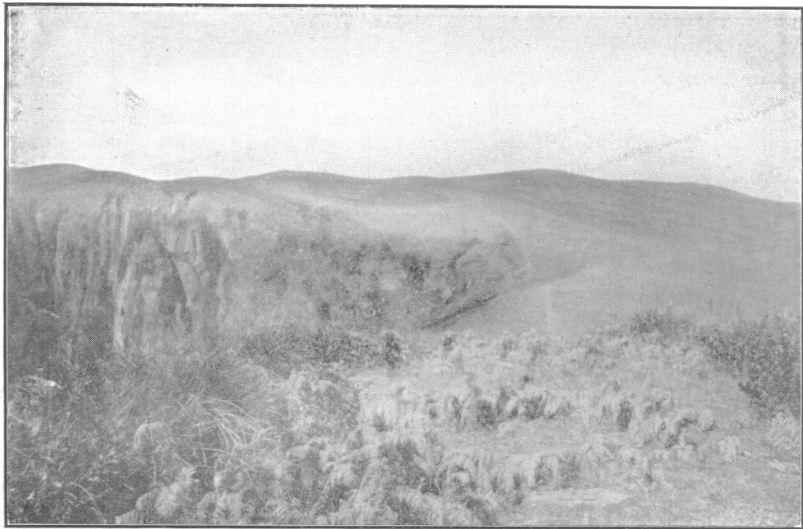


FIG. 5—At Kodaikanal west of Madura. The gently rolling surface of the elevated peneplain contrasted with the crest slope of the ancient sea cliff, shown dimly at the left, which here plunges directly down nearly 7,000 feet to the plain of marine denudation.

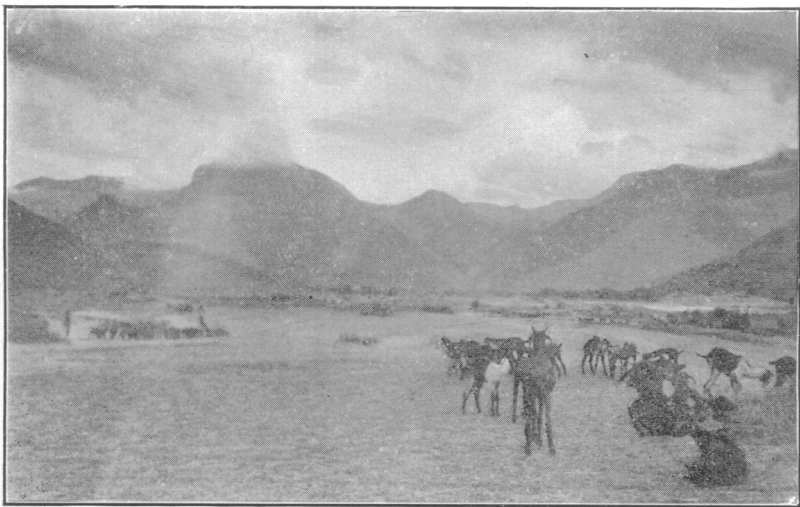


FIG. 6—Junction of the elevated peneplain and the infertile plain of marine denudation.

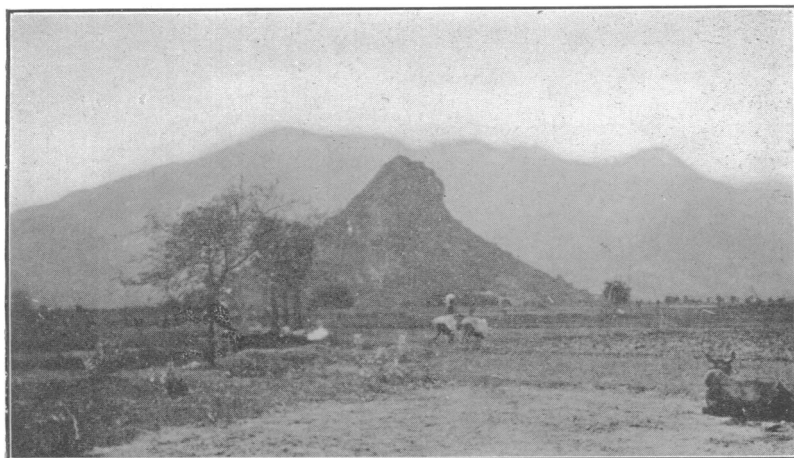


FIG. 7—An outlier, and beyond, the ancient sea wall. Their bases are connected with raised beaches.

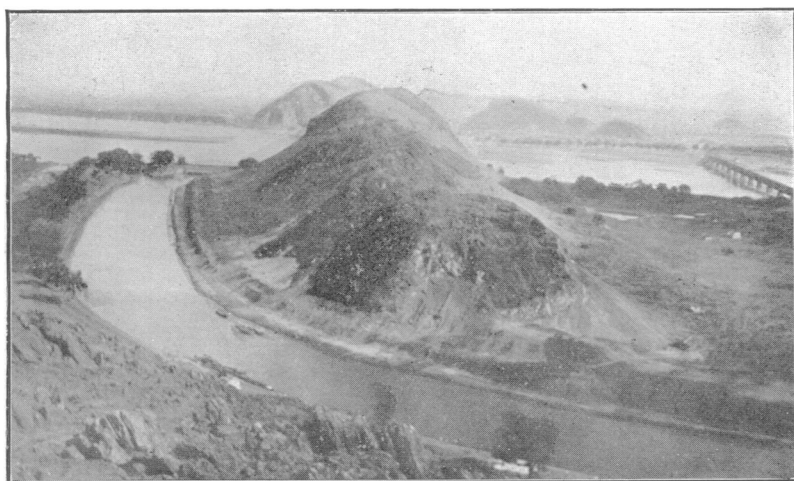


FIG. 8—Outliers whose summits record the former extension of the elevated peneplain, near Bezvada on the Kistna River. In the foreground is an irrigation canal. In the right distance large outliers closely grouped show a continuous even sky line suggestive of the perfection of the elevated peneplain before marine invasion

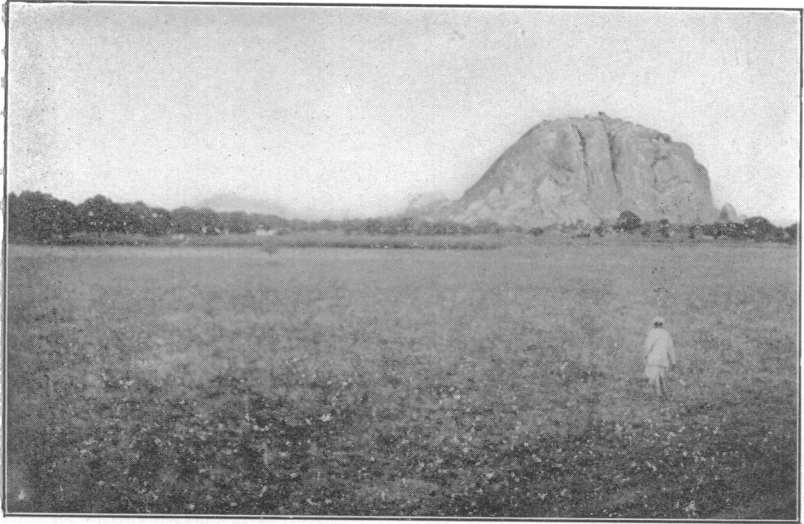


FIG. 9—A bare outlier on plain of marine denudation, near Madura, crowned with a Hindu temple and a Mohammedan mosque.

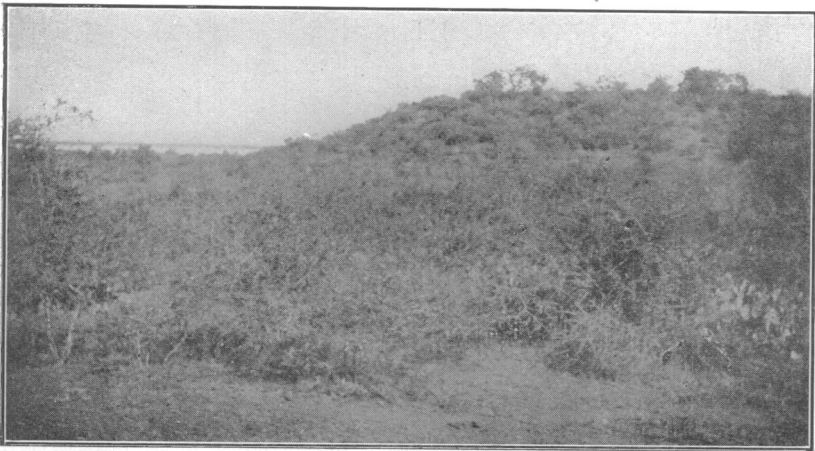


FIG. 10—A cuesta nose of the mature coastal plain west of Nellore. The Pennar is seen in the distance.

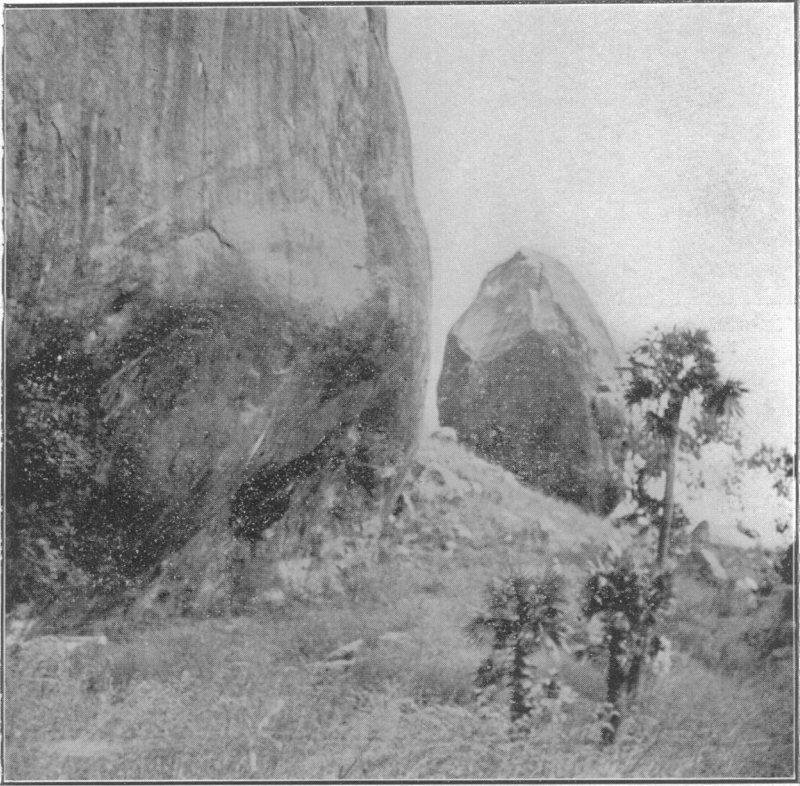


FIG 11—At the base of the outlier in Fig. 9 showing the results of marine erosion. The rim of the cave is sixty-five feet high.

over 130 feet above the present sea level, and where the maximum width of the plain is ten miles. The north and south extensions of the plain take on more and more the characteristics of youth, and finally are indistinguishable in surface features from the landward extension of its foundation, and from a young coastal plain, that will be described below, that overlaps it on the seaward flank. The structure of the mature coastal plain, however, is always individual and prevents confusion with any other feature. It is determined by the influence of alternate wet and dry seasons of weathering, under high temperatures, upon stratified rocks. The effect is a laterite in which the stratification is disguised by concretions, nodules, and small irregular tubes. The whole mass is rendered highly ferruginous by the process so that it has a conspicuous red color in contrast to the light grey sands of the young coastal plain. The surface of the marine denudation plain is sometimes lateritized but here the metamorphic structures are highly persistent.

Mature dissection of the central sections has developed *cuestas* that overlook inner lowlands which join the plain of marine denudation almost imperceptibly. The lowland has been eroded to and into the basal metamorphics. Insequent streams have made parts of *cuestas* stand out as headlands (a low one is shown in Fig. 10), from the summits of which excellent views are obtained across the lowland and denudation plain with its bold outliers, and at certain places, to the imposing even-crested sea wall beyond. Insequent erosion has converted a few former headlands into *inliers*. Extended consequent rivers have opened up wide valleys, thus isolating portions of the plain, and justifying reference to them, by early Indian geologists, as patches of low plateaus.

The gentle seaward slope of this plain ends, in some sections, at the crest of a short, steep slope, from the base of which extends the young coastal plain, as shown in the distance in Diagram 1. This relation would seem to indicate that during the time of deposition of the material of the young coastal plain, the sea consumed much of the mature coastal plain, and left the record of its work in the elevated sea cliff. This cliff is most evident in South India, near Cuddalore, a minor port, where it reaches a maximum height of forty-five feet.

Young Coastal Plain. A young coastal plain is indicated, along the outer margin of the Carnatic, in a little-eroded, nicely stratified, wedge-shaped deposit of unconsolidated sands and clays. (D, Diagram 1.) There are marine fossils in the deposits of the same species

as are now living in the bordering sea. The young coastal plain has an average width of about six miles and a slope of less than 2° . The seaward margin of this plain has the characteristics of a young coast line, *i. e.*, sand bars, lagoons, marshes, etc. Some of the lagoon floors have been raised so high that they are now flooded only during the spring tides of the rainy season. The surface of the plain continues as the sea floor with such a very gentle slope that in some parts a tidal fall of thirteen feet suffices to expose over two miles of sea floor. (Fig. 14.)

Deltas. The most important element geographically of the Carnatic is the delta land. It is this land that produces the larger part of the immense crop of cereals that the lowland yields. The largest of the deltas, that of the Godavari, has an area of a thousand square miles and supports a population of nearly two-thirds of a million. The delta of the Kistna and that of the Cauvery can each boast of almost equal area and population. Most of the other numerous rivers have deltas proportional in size to the area they drain. A glance at the map (Fig. 1), will serve to show how extensive the delta land is. Three conditions seem to favor this rather abnormal delta growth. One is the enormous quantity of water and sediment the rivers of the east coast bring to their mouths. This is accounted for by the size of the basins of these rivers. Their source is so near the west coast that their basin area is not far from the area of peninsular India itself. The second is the small amount of sediment necessary for deposition upon the very shallow sea margin for delta growth. And the third favoring condition is the very gradual uplift that has revealed the young coastal plain. The apexes of most of the deltas are of about the same altitude as the inner margin of this plain, although they are farther from the sea, and it would seem that their growth kept pace with that of the plain.

The Coast. Throughout the twelve hundred miles of the Coromandel, from the mouth of the Hugli, the distributary of the Ganges that connects Calcutta with the Bay of Bengal, to Cape Comorin, the coast land is a low sandy tract, with the exception of a few places in the vicinity of Vizágapatam where outliers come to the sea margin. Sand dunes are common all along the coast. Fig. 14 shows an unusually conspicuous line of them. With the exception of four ledges between Ganjam and Vizágapatam, and two about thirty miles south of Madras, this great stretch of coast has no rocks to interrupt the gently sloping, sandy, sea-margin floor. (Fig. 14.)

Careful measurements of Government Hydrographic Charts of

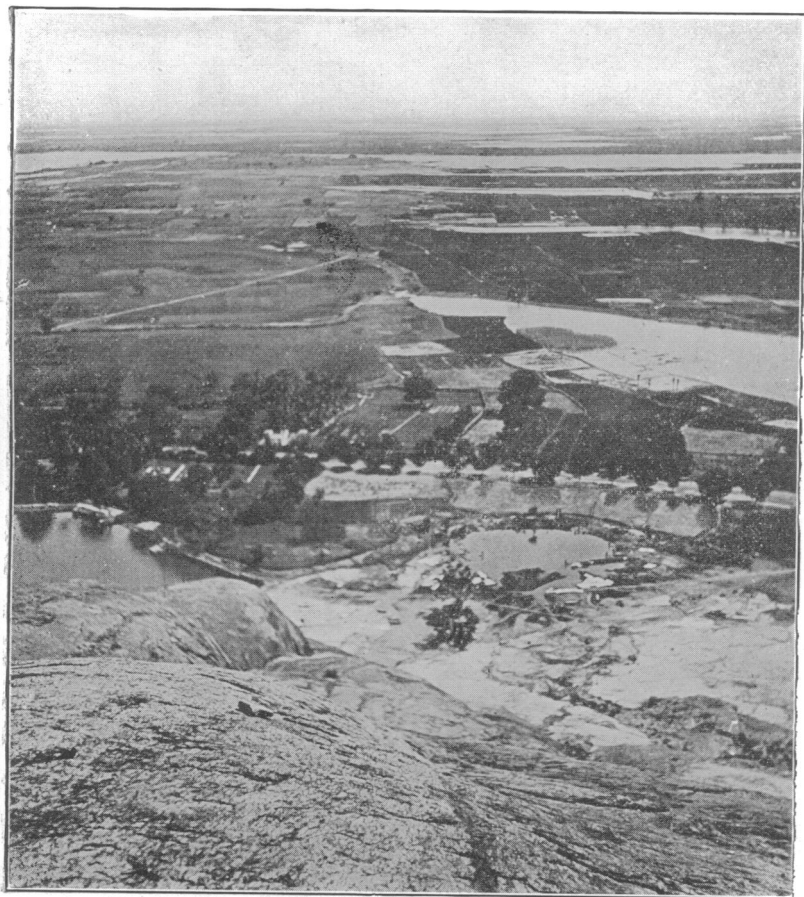


FIG. 12—From summit of outlier in Fig. 9 looking east across a low lying section of the mature coastal plain, and the young coastal plain. The water areas are irrigation "tanks."



FIG. 13—The bed of a deltaless river in the young coastal plain during the dry season. In the wet season a shallow torrent pours over it.

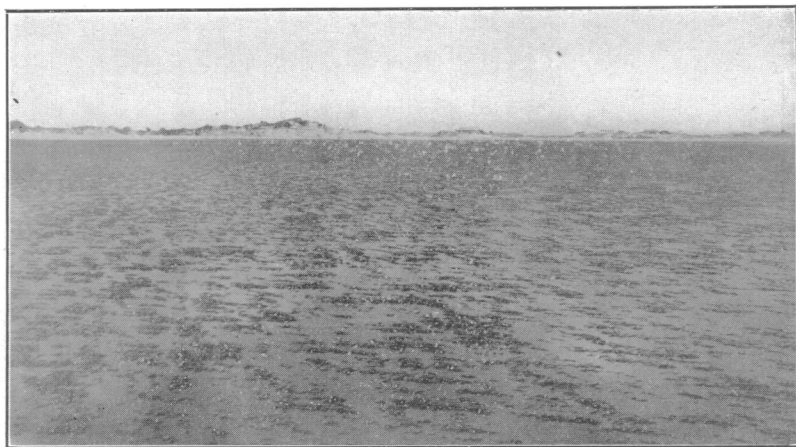


FIG. 14—Nearly one and a half miles from the coast line near Balasore, showing the very gently sloping expanse of sea floor, at low tide, that borders the young costal plain. A line of sand dunes separates the one from the other. The highest in this view is seventy-five feet,

this coast give the average distance of the ten fathom line as four and one-fifth miles from the shore; of the twenty fathom line, nine and one-half miles; and of the hundred fathom line, nineteen and one-seventh miles. The average distance of the five fathom line from the shore cannot be nicely ascertained from the charts, but an estimate would place it clearly over a mile. These figures indicate in a striking way the gentleness of the slope of the sea floor bordering this coastline of elevation.

In front of the large deltas these sea floor contours are close together, showing that the strong currents that play along the coast, under the alternating influence of the northeast and southwest trades, keep the projecting outer margins of the deltas well trimmed into a steeper slope. The quiet angles at the junctions of delta margins with the young coastal plain border, and especially between nearby deltas, have greatly favored the growth of strand plains. (Diagram 1.) These are clearly distinguished from the young coastal plain by the succession of beach ridges that mark the surface, prevailing cross-bedded structure, and by a lack of slope. When formed between deltas they sometimes enclose lakes as shown at E, Diagram 1.

Conclusion. Such is the general disposition of the physiographic areas along the Carnatic. There are, however, wide departures from this. For example, in the vicinity of Vizágápatam, a port one-third the way along the coast from the north, bold outliers stand forth even to the coast and permit the sea to etch cliffs and caves at their bases. One of these attains 1,500 feet in height. They form a pleasing variant in a coast that is edged with low sandy stretches throughout the rest of its great length. Here the denudation plain



DIAGRAM 3—Diagram of a riverside portion of a thin, low-lying stretch of the mature coastal plain, especially prevalent in the southern part of the east coast. The lateritized sediments are more resistant to erosion than the underlying metamorphic rocks.

extends forty miles before the wall of the Eastern Ghats is reached. There is no evidence of the mature coastal plain. The young coastal plain takes on the new relation of having the denudation plain as a foundation, and articulating with the numerous outliers extending out of it. Here then the material that would have made the mature coastal plain must have been stripped off by the retreating sea, or this part of the section was above sea level during the deposition of the mature coastal plain material elsewhere.

In the Madura section of South India the mature coastal plain is so low lying and its structures are so thin that it loses its most conspicuous characteristics. (Diagram 3.) Toward the inner margin it is represented by thin patches of lateritized sediments that fill shallow hollows of the denudation plain. There is no inner lowland. Outliers are rare here. One may travel long distances without seeing any. The young coastal plain is dwarfed in importance by a broad strand plain. It seems to be a product of the influence of the proximity of Ceylon to the mainland.

Again, near Madras the young coastal plain has a meager extent. The strand plain, which has had rapid growth since the harbor groins were built, almost outrivals it in width. Here, smaller type outliers invade the territory of the mature coastal plain.

The land forms of the East Coast therefore show clearly the result of a vacillating coast line, and what may be accomplished by the sea, destructively and constructively, under varying conditions of elevation and depression.

The elevated peneplain, marine denudation plain, the mature and young coastal plains, with the deltas, strand plains and islands, present conspicuously different environments, and their occupants, who have long been in the process of adaptation, yield correspondingly different responses. A second paper dealing with some of these responses will follow this one.

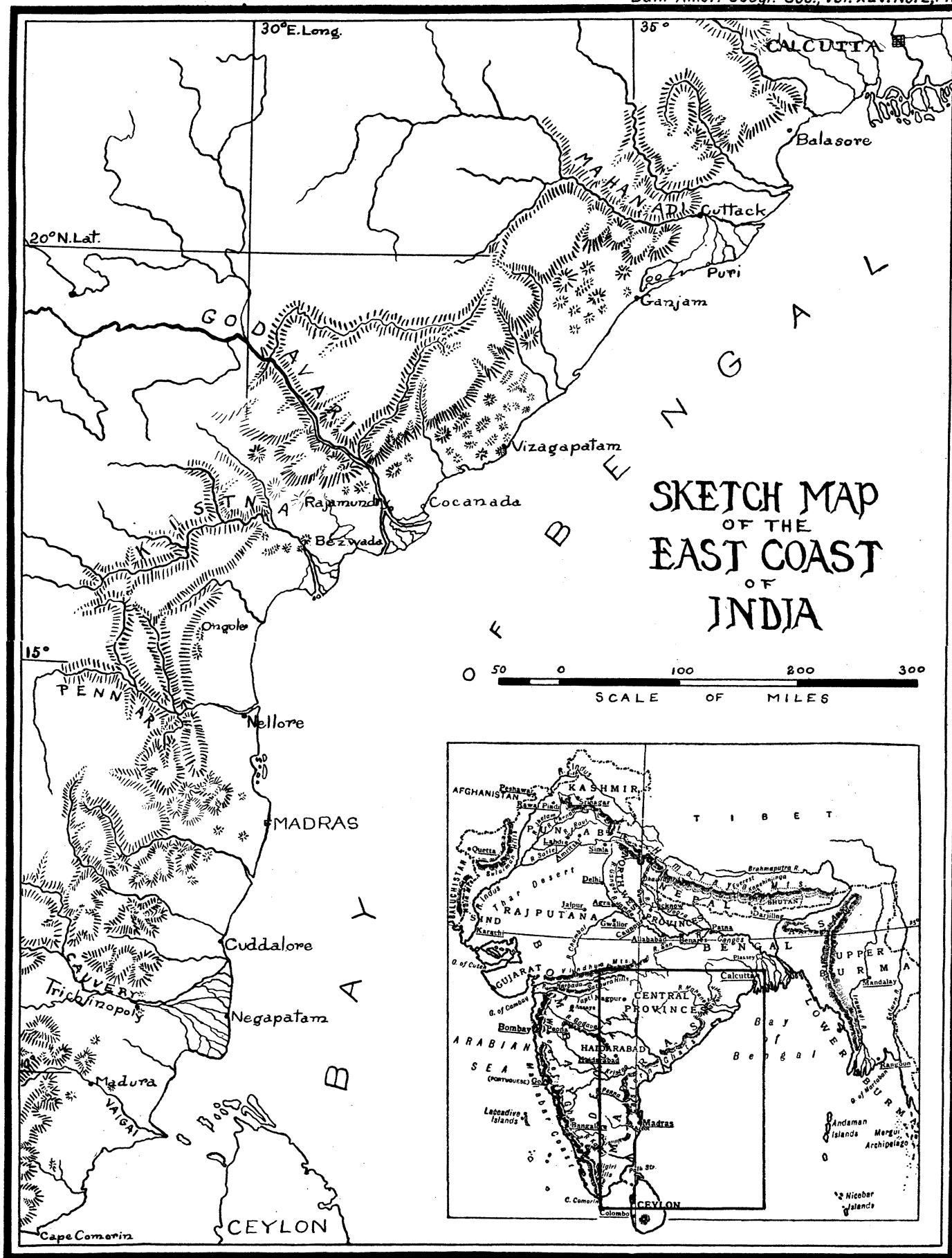


Fig.1